Indicator: Ozone Levels over North America (015)

Ozone is a gas present throughout the Earth's atmosphere. The environmental and human health implications of ground-level ozone are very different from those of ozone higher in the atmosphere, leading to the maxim: "Good up high, bad nearby" (EPA, 2003). In the troposphere, the part of the atmosphere closest to the Earth's surface, ozone poses significant health and ecological risks, but higher in the atmosphere, a thin natural layer of ozone shields and protects the Earth's surface from the sun's harmful ultraviolet (UV) rays. This ozone layer is found more than 10 miles above the Earth's surface, in the portion of the atmosphere known as the stratosphere. Releases of ozone-depleting substances—chemicals of human origin, such as chlorofluorocarbons and halons (see indicator 117) have damaged (thinned or depleted) the ozone layer. Stratospheric ozone depletion allows more UV radiation to reach the ground, which may in turn lead to more cases of skin cancer, cataracts, and other health problems (EPA, 1996).

Data mapped for this indicator are derived chiefly from the Total Ozone Mapping Spectrometer (TOMS), flown on NASA's Nimbus-7 satellite. The TOMS measures amounts of backscattered UV radiation at various wavelengths. Backscattered radiation levels at wavelengths where ozone absorption does and does not take place are compared with radiation directly from the sun at the same wavelengths, allowing derivation of the total amount of ozone in the Earth's atmosphere. Data are reported in Dobson Units (DU) which measure how thick the ozone layer would be if compressed in the Earth's atmosphere (at sea level and at 0°C.) One DU is defined to be 0.01 mm thickness at standard temperature and pressure.

What the Data Show

Figure 015-1 shows that total ozone measurements from the four monitoring stations declined during the period 1979 to 1993, after which they leveled off, though at a level lower than pre-1980. The large annual variation shown in each of the four cities is a result of ozone transport processes that cause increased levels in the winter and spring and lower ozone levels in the summer and fall at these latitudes

According to the most recent international scientific assessment, the global-average total column ozone during the period 1997 to 2001 was about 3 percent below average pre-1980 values (WMO, 2003). Trends over North America reflect this global phenomenon.

Indicator Limitations

- NOAA collects data on total column ozone using a combination of surface (Dobson Spectrophotometer) and satellite (Total Ozone Mapping Spectrometer (TOMS) and Solar Backscatter Ultraviolet (SBUV)) instruments. Once seasonal variance is removed all three instruments show very good agreement. SBUV instruments can produce data only for daylight-viewing conditions, so SBUV data are not available at polar latitudes during winter darkness.

Data Sources

Data provided by the National Oceanic and Atmospheric Administration (NOAA), 2003.
http://www.cpc.ncep.noaa.gov/products/stratosphere/winter_bulletins/nh_03-04/

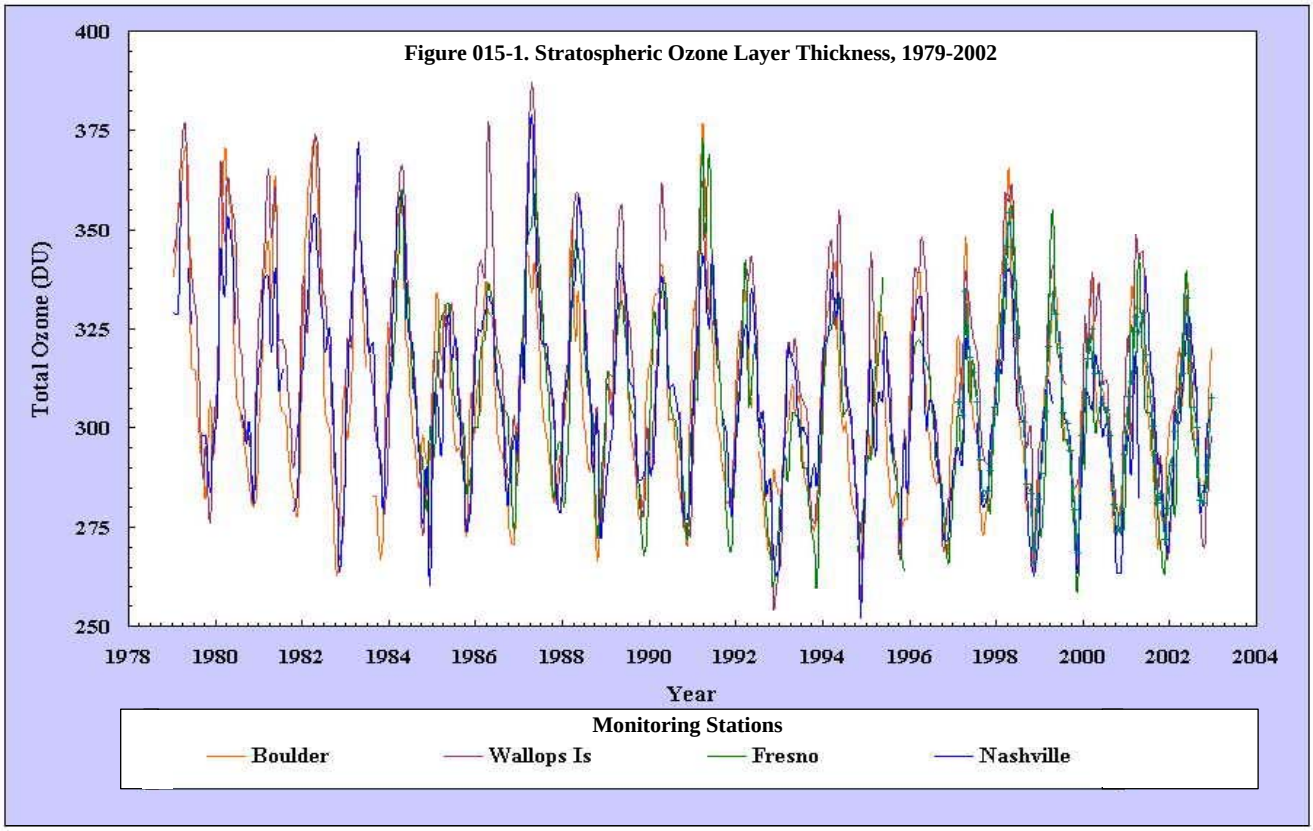
References

World Meteorological Organization, et al. Scientific Assessment of Ozone Depletion: 2002. Geneva, Switzerland. March 2003.

EPA, 1993. Ozone: Good Up High Bad Nearby, EPA 451/K-03-001. Washington, DC; US Environmental Protection Agency, Office of Air and Radiation, June 2003.
U.S. Environmental Protection Agency.

EPA, 1996. Air Quality Criteria for Ozone and Related Photochemical Oxidants, EPA 600-P-93-004F-cF. Research Triangle Park, NC; US Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, July 1996.

Graphics



R.O.E. Indicator QA/QC

Data Set Name: OZONE LEVELS OVER NORTH AMERICA
Indicator Number: 015 (89075)
Data Set Source: NOAA Climate Prediction Center
Data Collection Date: 1979-2002
Data Collection Frequency: ongoing
Data Set Description: Ozone Levels over North America
Primary ROE Question: What are the trends in outdoor air quality and effects on human health and ecological systems?

Question/Response

T1Q1 Are the physical, chemical, or biological measurements upon which this indicator is based widely accepted as scientifically and technically valid?

Data mapped for this indicator are derived chiefly from the Total Ozone Mapping Spectrometer (TOMS), flown on NASAs Nimbus-7 satellite. The TOMS measures amounts of backscattered UV radiation at various wavelengths. Backscattered radiation levels at wavelengths where ozone absorption does and does not take place are compared with radiation directly from the sun at the same wavelengths, allowing scientists to derive a total ozone amount in the Earth s atmosphere. The data for this indicator are presented in Dobson Units (DU) which measure how thick the ozone layer would be if compressed in the Earth s atmosphere (at sea level and at 0°C.) One DU is defined to be 0.01 mm thickness at standard temperature and pressure.

T1Q2 Is the sampling design and/or monitoring plan used to collect the data over time and space based on sound scientific principles?

NASA's most visible and best-known ozone research program is the Total Ozone Mapping Spectrometer (TOMS). Since the launch of the first TOMS aboard the Nimbus-7 polar-orbiting satellite in 1978, NASA has provided scientists with reliable, high-resolution daily maps of global ozone levels. Managed by NASA's Goddard Space Flight Center (GSFC), Greenbelt, Md., TOMS is a primary source of data on global ozone day-to-day variability and long-term trends. Ozone-depletion data from TOMS underpins several international agreements to phase out the use of CFCs and other ozone-depleting chemicals. A long-term, consistent record of ozone levels is essential to understanding and predicting ozone depletion. To ensure that ozone data will be available, NASA has been continuing the TOMS program using U.S. and international launches. On Aug. 15, 1991, the former Soviet Union launched a Meteor-3 satellite carrying a TOMS instrument provided by NASA. The Meteor-3/TOMS instrument ensured continuity of data when Nimbus-7/TOMS ceased operating in May 1993. The Japanese Advanced Earth Observations Satellite (ADEOS) carried a fourth TOMS into orbit when it launched in 1996.

T1Q3 Is the conceptual model used to transform these measurements into an indicator widely accepted as a scientifically sound representation of the phenomenon it indicates?

The most recent authoritative assessment of the Earth s stratospheric ozone is the Scientific Assessment of Ozone Depletion: 2002 (Scientific Assessment Panel, 2003), conducted under the auspices of the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO).

T2Q1 To what extent is the indicator sampling design and monitoring plan appropriate for answering the relevant question in the ROE?

Ozone in the stratosphere protects humans and ecosystem from harmful UV-radiation, is a key aspect of air quality that affects humans an ecosystems. The monitoring data cover the entire range of situations in which people and ecosystems are exposed to natural UV radiation.

T2Q2 To what extent does the sampling design represent sensitive populations or ecosystems?

The TOMS data cover the entire earth surface, so UV-B exposure can be monitored for any UV-B sensitive system, subject to the minimum resolution of the sensor.

T2Q3 Are there established reference points, thresholds or ranges of values for this indicator that unambiguously reflect the state of the environment?

No.

T3Q1 What documentation clearly and completely describes the underlying sampling and analytical procedures used?

Nimbus-7 was launched on October 24, 1978; measurements began about a week later. For the purpose of obtaining daily high-resolution global maps of atmospheric ozone, TOMS measured the solar irradiance and the radiance backscattered by the Earth's atmosphere in six select wavelength bands in the ultraviolet. TOMS scanned in 3-degree steps to 51 degrees on each side of the subsatellite point, in a direction perpendicular to the orbital plane. Consecutive cross-scans overlapped, creating a contiguous mapping of ozone. The Nimbus-7 TOMS Version 7 User's Guide contains information about the data products derived from the measurements made by the Total Ozone Mapping Spectrometer (TOMS) experiment aboard the Nimbus 7 satellite. It discusses the calibration of the instrument, the algorithm used to derive ozone values from the measurements, the uncertainties in the data, and the organization of the data products. The data begin October 31, 1978 and end May 6, 1993. These data are archived at the Goddard Space Flight Center Distributed Active Archive Center (DAAC). Since the previous release of TOMS data, continuing study of the TOMS data products and the process of deriving them has led to many improvements in the generation the data. A copy of the Nimbus-7 TOMS Version 7 User's Guide can be downloaded from the following web-site - http://toms.gsfc.nasa.gov/n7toms/n7sat.html.

T3Q2 Is the complete data set accessible, including metadata, data-dictionaries and embedded definitions or are there confidentiality issues that may limit accessibility to the complete data set?

Data from Nimbus-7 TOMS (11/1978 through 05/1993) and Earth Probe TOMS (08/1996 through 08/2003) have been reprocessed and were distributed at the 2004 Quadrennial Ozone Symposium in June 2004. A 2 DVD set contains data and images from both instruments for all of the TOMS products: ozone, aerosol, reflectivity, and erythemal UV. Copies of the DVD's can be obtained from the Goddard Space Flight Center's Distributed Active Archive Center (DAAC)- http://daac.gsfc.nasa.gov/data/dataset/TOMS/DVD-ROMs. Version 8 data are now available for the entire Nimbus-7 data record (November 1978 through May 1993) and for the Earth Probe data record from August 1996 through August 2003 via anonymous ftp as zip files. Each zip file contains the compressed individual files - http://daac.gsfc.nasa.gov/www/get_data.shtml.

T3Q3 Are the descriptions of the study or survey design clear, complete and sufficient to enable the study or survey to be reproduced?

Launched on 25 October 1978 from Vandenberg Air Force Base, California, the Nimbus-7 spacecraft was the last in a series of operational weather satellites operated by the US National Oceanic and Atmospheric Administration (NOAA) and the US National Aeronautics and Space Administration (NASA). Nimbus-7 was placed in a sun-synchronous orbit at an altitude of 955 km. Equatorial crossings are local noon for ascending node and local midnight for descending node. Spacecraft inclination is 99.1 degrees, with a leeward latitude of 80.77 degrees. Orbital period is 104.15 minutes, and consecutive equator crossings are separated by 26.1 degrees longitude. The communications and data handling subsystem, which manages all information flow for the Nimbus-7 platform, is composed of the S-band communications system and tape recorder subsystem. The S-band communication system includes the S-band command and telemetry system , the data processing system and the command clock. The S-band command and telemetry system consists of two S-band transponders, a command and data interface unit, four earth view antennas, a sky view antenna, and two S-band transmitters (2211 MHz). Commands are transmitted to the observatory by pulse code modulation, phase-shift keying/frequency modulation/phase modulation of the assigned 2093.5 MHz S-band uplink carrier. Stored command capability provides for command execution at predetermined times. Additional information is available at http://toms.gsfc.nasa.gov/n7toms/nimbus7tech.html. The communications and data handling subsystem, which manages all information flow for the Nimbus-7 platform, is composed of the S-band communications system and tape recorder subsystem. The S-band communication system includes the S-band command and telemetry system , the data processing system and the command clock. The S-band command and telemetry system consists of two S-band transponders, a command and data interface unit, four earth view antennas, a sky view antenna, and two S-band transmitters (2211 MHz). Commands are transmitted to the observatory by pulse code modulation, phase-shift keying/frequency modulation/phase modulation of the assigned 2093.5 MHz S-band uplink carrier. Stored command capability provides for command execution at predetermined times. Additional information is available at http://toms.gsfc.nasa.gov/n7toms/nimbus7tech.html

T3Q4 To what extent are the procedures for quality assurance and quality control of the data documented and accessible?

The Nimbus-7 TOMS Version 7 User's Guide contains information about the data products derived from the measurements made by the Total Ozone Mapping Spectrometer (TOMS) experiment aboard the Nimbus-7 satellite. It discusses the calibration of the instrument, the algorithm used to derive ozone values from the measurements, the uncertainties in the data, and the organization of the data products. A description of the Dobson Spectrophotometer’s accuracy is available at: http://www.cmdl.noaa.gov/ozwv/dobson/papers/report13/report13.html.

T4Q1 Have appropriate statistical methods been used to generalize or portray data beyond the time or spatial locations where measurements were made (e.g., statistical survey inference, no generalization is possible)?

Not Applicable.

T4Q2 Are uncertainty measurements or estimates available for the indicator and/or the underlying data set?

A comprehensive study of the instrument properties and their variations with time has been made, producing a more accurate derivation of radiances from the raw instrument counts. Improvements have been made to the input physical data, the treatment of physical processes, and the parameterizations of atmospheric conditions used in the radiative transfer calculations that are part of the algorithm. The process of deriving ozone and reflectivity has been modified to incorporate a linear correction for wavelength dependence in the reflectivity, other wavelength-dependent physical effects, or wavelength-dependent errors. The resulting Version 7 TOMS data have a long-term 2s calibration uncertainty of ±1.5 percent in total ozone over 14.5 years. In addition, a number of local anomalies in the earlier data have been eliminated. More details can be found in the Nimbus-7 TOMS Version 7 User's Guide.

T4Q3 Do the uncertainty and variability impact the conclusions that can be inferred from the data and the utility of the indicator?

No

T4Q4 Are there limitations, or gaps in the data that may mislead a user about fundamental trends in the indicator over space or time period for which data are available?

TOMS provides no data during nighttime or during the longer periods of darkness in polar regions.